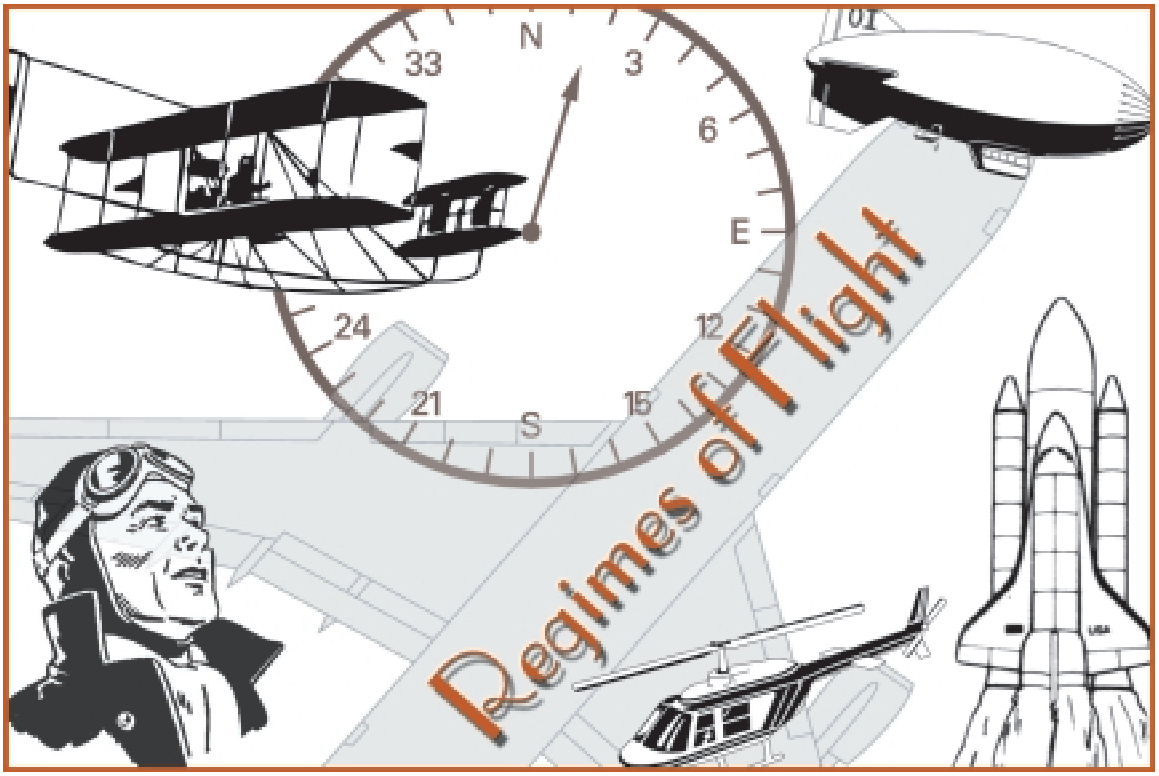
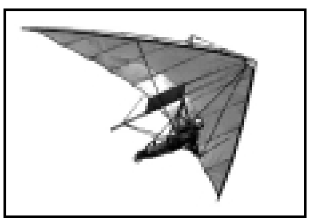
Student Handouts

Readings and Comprehension Worksheets

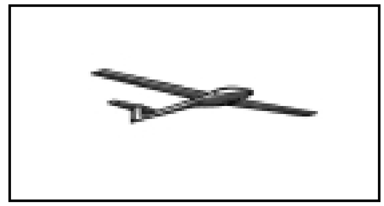


Student Reading
Regimes of Flight

After the invention of the airplane, designers and engineers created new aircraft for a variety of uses. Airplanes became a part of daily life. Aircraft were used regularly to ship cargo and to transport people. Over time, the speed of aircraft has increased. We put aircraft into groups based upon how fast they can fly. We call these groups the speed regimes (pronounced "ra-jeems") of flight. There are five basic speed regimes. These include the earliest aircraft to the most modern.

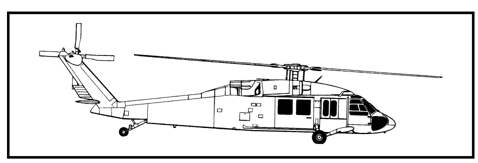


The first speed group flies in the low speed regime. Aircraft in this group travel at speeds between 0 and 100 miles per hour (mph).These tend to be lightweight vehicles with a small engine or no engine at all. The aircraft in this group include the earliest types of aircraft, such as kites, balloons and early airplanes. Modern aircraft in this speed regime are hang gliders, balloons, ultralights and airships (blimps, dirigibles).

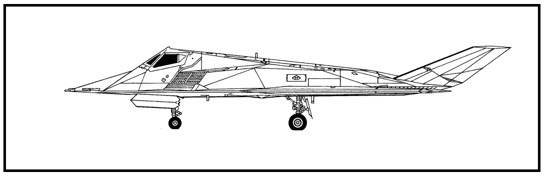


The second group flies in the medium speed regime. These aircraft fly between 100 and 350 mph. These vehicles are usually airplanes with straight, thick wings.This category includes sailplanes, biplanes, propeller planes, helicopters and autogyros. Early German-made planes like the Fokker and the Junkers are in this category. Small planes, like the modern Cessna and Beechcraft, are also grouped within this speed regime.

The third group flies in the high speed regime. The aircraft in this category are the powerful propeller airplanes and jet planes that fly between 350 and 700 mph. These vehicles usually have thin, sweepback

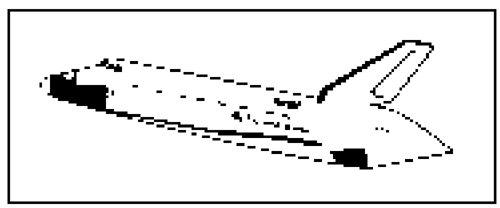


wings. The greater the sweep, the faster they can go. The fuselage is a sleek shape. The Boeing 747 Jumbo Jet, the Lear Jet, the Sikorsky Blackhawk helicopter and many fighter planes fly within this speed regime.



The fourth group flies in the supersonic speed regime. This group includes aircraft that can go faster than the speed of sound, which is approximately 760 mph. The supersonic speed regime goes up to 5 times the speed of sound. These vehicles have high-powered jet engines, a sleek fuselage and super thin, sweepback or delta wings. The Concorde, the F-15 Eagle, and the SR-71 Blackbird are some examples of airplanes that can fly at supersonic speeds. The X-1 was the first plane to fly faster than the speed of sound.

The last speed regime is hypersonic flight, which is between 5 and 10 times the speed of sound. This is 3,500-7,000 mph. These vehicles have high-powered rocket engines with short, thin wings. They have highly advanced heat protection systems to protect the aircraft from the extreme heat faced during re-entry. Rockets travel at these speeds as they accelerate into Earth orbit. Also, re-entry capsules like Apollo travel at these speeds as they descend from orbit. The best known examples of hypersonic aircraft are the X-15 and the space shuttle



which flies through all of the speed regimes when it re-enters Earth's atmosphere. The space shuttle is coasting from a very high speed and high altitude when it flies hypersonically. There is currently no aircraft that can cruise at these speeds, however NASA is currently researching flight at hypersonic speed using experimental prototypes like the X-33 and X-34.

Student Worksheet: Regimes of Flight

Directions: Match the category from the box on the right to the descriptions given on the left. Place the letter in the blank next to the proper description.

_____ 1. 100 - 350 mph

_____ 2. kites, balloons, airships

_____ 3. high-powered jet engines, sleek fuselage with super thin, swept-back or delta wings

_____ 4. 350 - 700 mph

_____ 5. high-powered rocket engines with thin, short wings

_____ 6. Cessna, Fokker, Junkers

_____ 7. Mach 5 to Mach 10

_____ 8. lightweight structures with small or no engines

_____ 9. greater than 760 mph, but less than Mach 5

_____ 10. propeller types with straight, thick wings

_____ 11. rockets, Space Shuttle, X-15

_____ 12. 0 - 100 mph

_____ 13. Boeing B-47, Lear Jet, Vickers Viscount

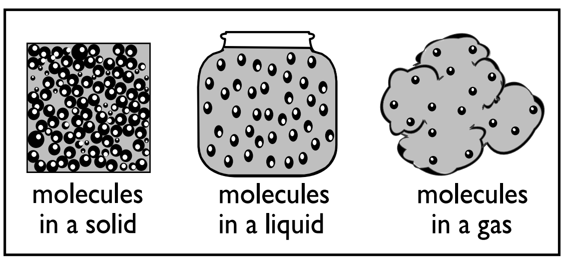
_____ 14. Concorde, F-15, Eagle, Stealth

_____ 15. powerful propeller or jet-powered engines with thin, sweepback wings and a sleek fuselage

Category:
L) low speed
M) medium speed
H) high speed
SS) supersonic speed
HS) hypersonic speed

Student Reading
Speed of Sound

Sound waves can travel through air, water or even metal. In fact, sound can travel through anything made up of molecules. These molecules carry the sound waves by bumping into each other, like Dominoes knocking each other over. Gases, liquids, and solids are all made up of molecules. So how fast does sound travel? It depends on what is carrying the sound. Sound waves do not travel at the same speed through gases, liquids, and solids. The speed of sound depends on how close together the



molecules are. If they are close together, as in a liquid, they can bump into each other more easily and carry the sound wave. In a gas, the molecules are farther apart, so sound waves are slower. Each molecule of a gas has to travel farther to bump into its neighbor. As you can see, to know the speed of sound, you have to pick a material. Let's pick air.

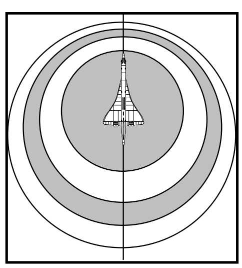
How fast is the speed of sound in air? Well, as one rises higher in the Earth's atmosphere the air becomes thinner. The atmosphere is thinner because the molecules of air are actually farther apart. With molecules farther apart, the sound wave goes slower. Therefore, the speed of sound in air depends on how high up in the sky you are. Let's pick sea level as our height.

So, how fast is the speed of sound, in air, at sea level? It is about 760 mph. That means it travels about one mile in five seconds! Have you ever heard a band performing its music live on stage, but you are seated a great distance away? Have you noticed that you can see the drummer hit the drum before the sound of the drum reaches your ears? Or have you noticed that thunder can take a long time to reach you after a lightning bolt hits? This is because, although 760 mph seems fast, it still takes a while for sound to travel to you.

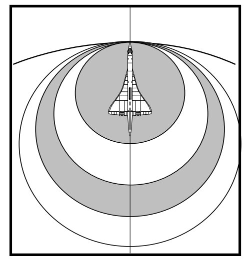
If an airplane is flying slower than the speed of sound, we say it is moving at **subsonic** speed. If it is flying at the speed of sound, it is traveling at **sonic** speed. If it is flying faster than the speed of sound, it is traveling at **supersonic** speed. When we refer to the speed of sound, we measure it in **Mach** numbers. So, if an airplane is traveling at the speed of sound, we say it is flying at Mach 1. If it is traveling at two times the speed of sound, we say it is flying at Mach 2. The word "Mach" comes from the Austrian scientist Ernst Mach who studied airflow and the speed at which sound travels.

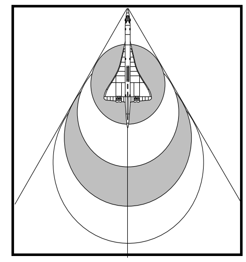

Mach

When an airplane moves through the air at speeds lower than the speed of sound, the air molecules ahead of the plane can get out of the way and pass around the plane. The air behaves like water does when you swim through it.



However, when an airplane moves faster than the speed of sound, the air doesn't have enough time to get out of the way. Instead, it piles up in front of the airplane





and forms a shock wave. So, if an airplane were traveling toward you at the speed of sound, you would not hear it coming. That's because the sound it makes is traveling at the same speed as the plane itself. If that same plane flew toward you at a speed faster than the speed of sound, you would not hear it until after it had passed.

Student Worksheet: Speed of Sound

Directions: Use the student reading "Speed of Sound" to help you answer the questions below.

1. In order for sound to move it must have a medium through which to travel. List three media through which sound travels.

2. What is the speed of sound in miles per hour? Under what conditions is this speed measured?

3. Draw a picture of how sound waves coming from a subsonic aircraft move through the air at subsonic speed.

4. Draw a picture of how sound waves coming from a supersonic aircraft move through the air at supersonic speed.

Student Reading: Aeronautics of the Space Shuttle

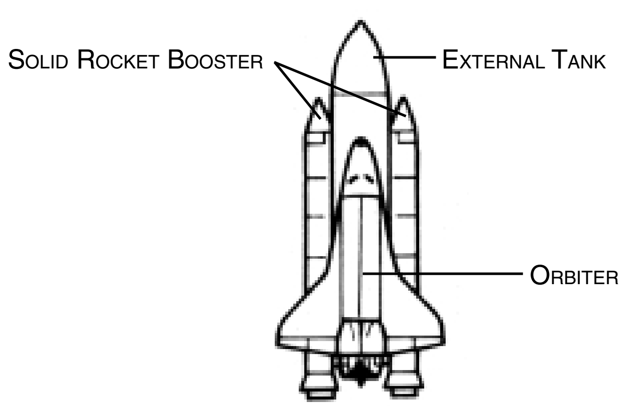
The Space Shuttle is a Lifting Body

On August 12, 1977 a specially modified Boeing 747 jetliner was giving another aircraft a piggyback ride. Approximately 24,000 feet above the Mojave Desert a high-tech glider was released from its flying perch. It glided effortlessly without engine power to a smooth landing on the desert floor. A new era in space transportation had begun.

That high-tech glider was the space shuttle. The space shuttle is designed to simply ferry or "shuttle" people, satellites and other cargo between earth and space. It is a reusable spacecraft unlike any other that had come before it. It is a more efficient and economical vehicle as compared to its predecessors: capsules and rockets. The space shuttle, with a shape like a bulky glider, is actually a lifting body. A lifting body is a specially constructed spacecraft that cannot launch under its own power, but needs additional rocket engines for thrust. The space shuttle is a unique lifting body in that it is a high-tech glider.

Basic Structure

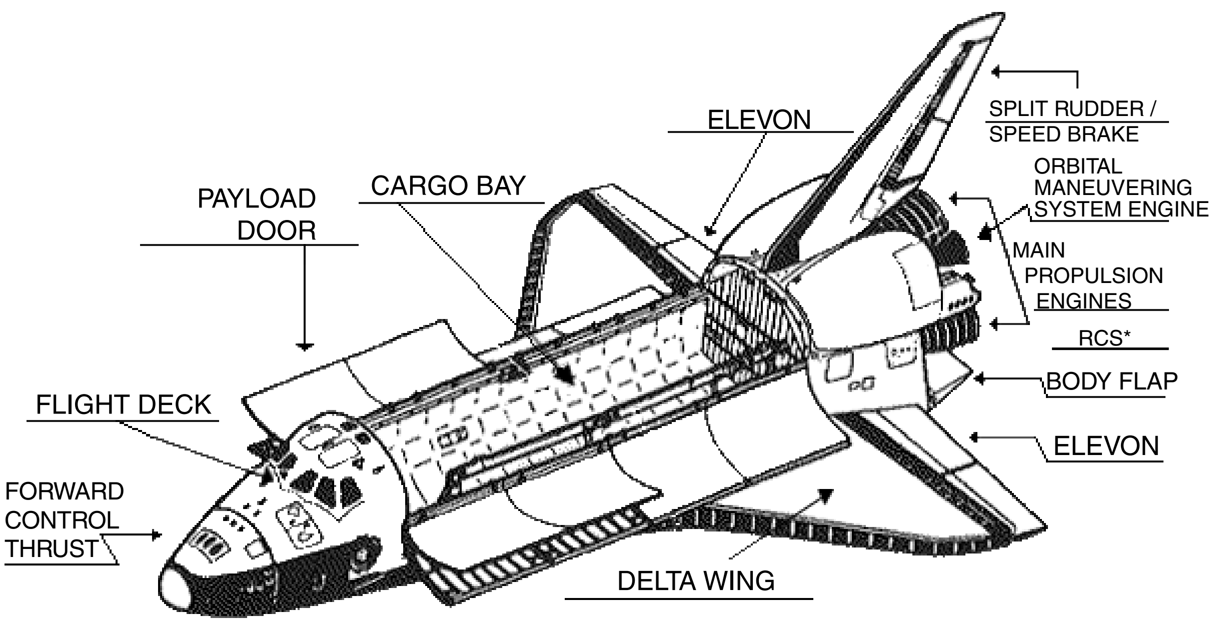
The space shuttle is made up of four parts: an orbiter (the shuttle itself), two solid rocket boosters (both reusable) and one external fuel tank (which is not reusable). This space craft is launched in an upright position attached to the 2 solid rocket boosters and the external fuel tank. At launch, the orbiter's 3 main engines are fired (fueled by the external fuel tank) as well as the solid rocket boosters. Together they provide the shuttle with the millions of pounds of thrust to overcome the earth's gravitational pull.



Aeronautics of the Space Shuttle (continued)

<u>The Orbiter as a High-Tech Glider</u>

The orbiter is shaped much like an airplane. It has many of the same parts as an airplane except for its engine configurations. The orbiter has wings that create lift. It uses a double-delta wing configuration to achieve the most efficient flight during hypersonic speed as well as providing a good lift-to-drag ratio during landing. For control, each wing has an "elevon". An elevon is a combination of an <u>elev</u>ator and an ailer<u>on</u>. On an airplane, the elevator controls the motion of pitch (nose up, nose down). On most airplanes, the elevator is located on the horizontal stabilizer as part of the tail section. The ailerons are found on most airplanes at the trailing edge of each wing. Ailerons control an airplane's roll motion. Because of the orbiter's delta wing configuration, the elevators and ailerons are combined as elevons and placed at the trailing edge of each wing. The orbiter's vertical stabilizer (fin) has the rudder which controls its yaw (nose left, nose right). The split-rudder on the orbiter works as a rudder and also as a speed brake (found on most airplanes as a spoiler located on the wing). It does this by splitting in half vertically and opening like a book. This deflects the airflow, increases drag and decreases the orbiter's speed as it rolls along the runway upon landing.



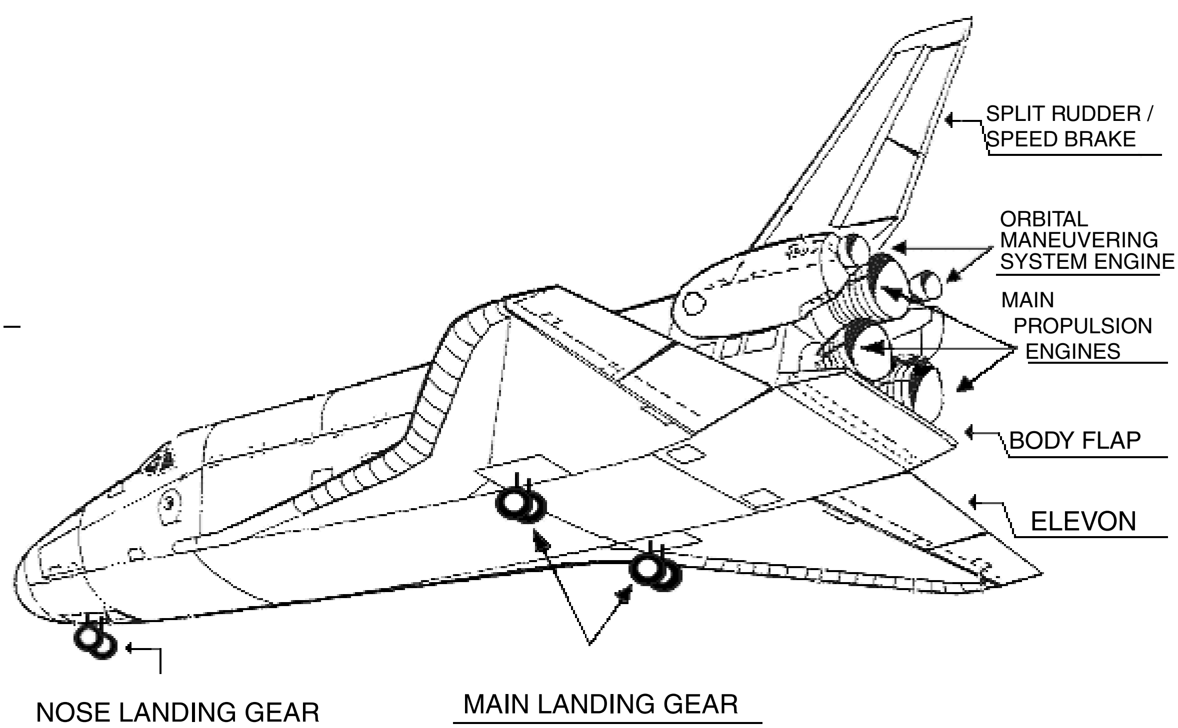
* RCS = REACTION CONTROL SYSTEM

Aeronautics of the Space Shuttle (continued)

The airplane-like control surfaces on the orbiter are useless in the vacuum of space. However, once the orbiter re-enters the earth's atmosphere, these control surfaces interact with the air molecules and their airflow to control the orbiter's flight path.

The engines are the major difference between this high-tech glider and airplanes. The orbiter has the OMS (orbital maneuvering system) engines as well as the RCS (reaction control system) engines. The shuttle maneuvers into orbit using its orbital maneuvering system (OMS). The OMS has 2 rocket engines located on the outside of the orbiter, one on each side of the rear fuselage. These rockets give the orbiter the thrust it needs to get into orbit, change its orbit, and to rendezvous with a space station or another space vehicle. The OMS is also used to exit orbit for re-entry into the earth's atmosphere.

The second set of small engines is the reaction control system (RCS) engines. The RCS engines allow the commander to perform the motions of roll, pitch and yaw while the orbiter is moving out of orbit and into re-entry of the earth's atmosphere. The RCS engines are also used while the orbiter is maneuvering in the upper atmosphere.



Aeronautics of the Space Shuttle (continued)

Re-entry and Landing

The commander begins the de-orbit burn by firing the orbiter's engines to slow its speed and take it out of orbit. Using the RCS engines, the orbiter is turned around so that it is moving backwards at a slower speed. To maneuver the orbiter while it is in this position, the commander uses the RCS engines to control roll, pitch and yaw motions. The OMS engines (space engines) are then fired, taking the orbiter out of orbit and thrusting it into the earth's upper atmosphere. The RCS engines are used one last time to turn the orbiter around so that it is moving nose forward and pitched up slightly. In the upper reaches of the atmosphere the vehicle's motions of yaw, pitch and roll are controlled by the RCS engines. As the atmosphere thickens, the airplane control surfaces become usable. The orbiter re-enters the atmosphere at a high angle of attack (about 30 degrees). This high angle of attack is used to direct most of the aerodynamic heating to the underside of the vehicle where the heat resistant tiles give the greatest amount of protection.

At an altitude of approximately 30 miles, the orbiter makes a series of maneuvers and S-turns to slow its speed. At 9.5 miles in altitude and at a speed of Mach 1, the orbiter can be steered using its rudder. The on-board computers fly the orbiter until it goes subsonic (slower than the speed of sound: Mach 1). This happens about 4 minutes before landing. At this time the commander takes manual control of the orbiter and flies a wide arc approach. At 7.5 miles from the runway, the orbiter is flying about 424 miles per hour at an altitude of 13,365 feet. About 2 miles from the runway, the orbiter is flying at nearly 360 miles per hour on a glide slope of 22 degrees.

Once lined up with the runway on approach, the orbiter continues its steep glide slope of 18 - 20 degrees. The commander levels the descent angle at a final glide slope of 1.5 degrees by performing a "flare maneuver". The nose of the orbiter increases its pitch (noses up) which slows its speed. The orbiter touches down at a speed of about 215 miles per hour. It is slowed and eventually brought to a stop by the speed brake, wheel brakes and a drag chute.

It is this unique aerospace vehicle, a lifting body, that launches like a rocket, orbits like a spacecraft and lands like a glider that continues to link earth and space.

Student Worksheet: Aeronautics of the Space Shuttle

Directions: After reading "Aeronautics of the Space Shuttle", answer each question below by circling the letter of the correct answer.

1. Name the vehicle that is an example of a lifting body.

   A. a Boeing 747
   B. a glider
   C. the orbiter

2. The orbiter uses what type of wing?

   A. delta wing
   B. sweepback wing
   C. straight wing

3. Which part of the space shuttle is NOT reusable?

   A. orbiter
   B. external fuel tank
   C. solid rocket booster

4. Name the "space engines" used by the orbiter to enter, exit and change orbit.

   A. solid rocket booster
   B. orbital maneuvering system
   C. reaction control system

5. Name the airplane control surface that is on the trailing edge of the orbiter's wings.

   A. aileron
   B. rudder
   C. elevon

6. Name the engine system that is used to control the orbiter's motions of roll, pitch and yaw while it is in the upper atmosphere.

   A. reaction control system (RCS)
   B. orbital maneuvering system (OMS)
   C. orbiter reaction system (ORS)

Student Worksheet: Aeronautics of the Space Shuttle (continued)

7. What is the purpose of the S-turns during landing?

    A. to reduce heat
    B. to slow the orbiter's speed
    C. to burn extra fuel

8. The orbiter's split-rudder is used to do what?

    A. control yaw
    B. slow the orbiter
    C. both of the above

9. The orbiter lands on the runway moving at about what speed?

    A. 424 mph
    B. 215 mph
    C. Mach 1

10. The major difference between the orbiter and an airplane is found with what part?

    A. elevons
    B. wings
    C. engines

11. An elevon is a control surface that combines which two control surfaces?

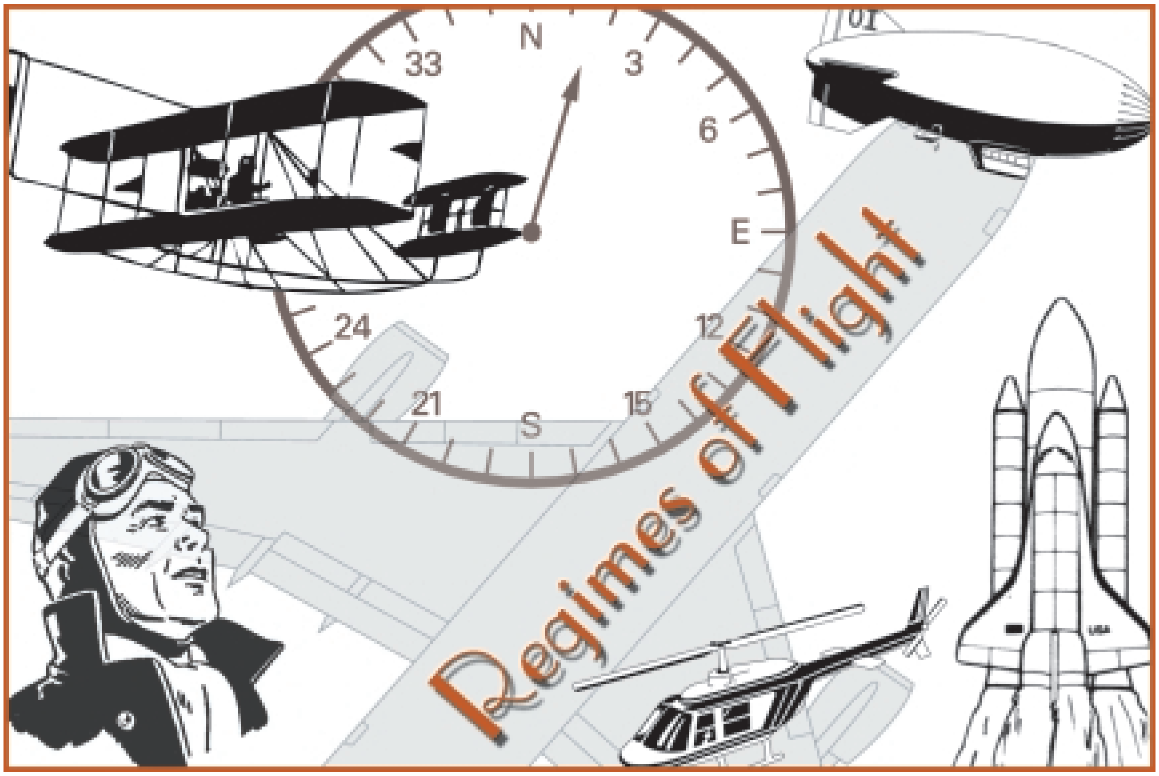
    A. aileron and elevator
    B. elevator and rudder
    C. wing and aileron

12. At what speeds does the orbiter fly?

    A. hypersonic
    B. supersonic and subsonic
    C. all of the above

Student Handouts

Additional Student Activities / Projects



Student Activity Sheet: Aircraft Trading Cards

Directions: Create your own Aircraft Trading Card. On the front of your Trading Card put the aircraft's name and below that draw a picture of the aircraft. On the back of the Trading Card record these statistics:

- Type of aircraft (airship, fixed wing, helicopter)
- Flight Regime (low, medium...)
- Year Built
- Purpose: For what was it used?
- Specifications:
    - Type of engine (propeller, rotor, jet)
    - Wingspan
    - Length
    - Height
    - Weight

Use the example below to help you design your Trading Card.

Front	**Back**

Aircraft Name
 	
Aircraft Drawing
	Aircraft Name:
	
	• **Type of Aircraft**
	• **Flight Regime**
	• **Year Built**
	• **Purpose**
	• **Specifications**
	    • **Type of engine**
	    • **Wingspan**
	    • **Length**
	    • **Height**
	    • **Weight**

Use the example below to help you design your Trading Card.

X-33 Advanced Technology Demonstrator

Front

X-33 Advanced Technology Demonstrator

Type of aircraft: Reusable Launch Vehicle (RLV)

Flight Regime: hypersonic, supersonic, subsonic

Year Built: 1999

Purpose: Demonstrate new technologies needed for a Reusable Launch Vehicle that will launch like a rocekt and land like an airplane.

Specifications

Type of engine: aerospike rocket engine

Wingspan: none given

Length: 127 feet

Height: none given

Weight: 2,186,000 lbs.

Back

Aircraft Trading Card
(Suggestion List)

Hindenburg (airship)
USS Macon (airship)
Stealth/Spirit
Fokker Monoplane
Mustang
ER-2
U-2
SR-71 Blackbird
AD-1
Boeing 707
Boeing 747
Pathfinder
Concorde
Boeing 314 Clipper
Lockheed Constellation
Spirit of St. Louis (Ryan Monoplane)
Graf Zeppelin
The Hawk (Percy Pilcher's Glider)
The (Wright) Flyer
Bleriot XI
Royal Vauxhall Balloon (or Great Balloon of Nassau)

Vickers Viscount
Spitfire
Hawker Hurricane
Gossamer Condor
Passarola (Great Bird)
Montgolfiere (balloon)
Le France (balloon, 1884)
Avion III (Ader)
Sopwith Camel
Sikorsky Russian Knight
Messerschmitt
de Havilland Comet I
Autogiro
Bell 206 Jetranger
Hawker Siddeley Harrier
Bell Boeing V-22 Osprey
Deperdussin racer (1913)
Sikorsky R-4 Hoverfly (1943)
Golden Flier (Curtiss)
Apache (helicopter)
Tiger Moth (aerobatic airplane)
Optoca

Aircraft Trading Card
(Suggestion List) - *continued*

Rockwell Sabreliner

No. 19 Demoiselle (1907)

Eipper Quicksilver

Lockheed Electra (1934)

Curtiss Model-D Pusher (1911)

USS Akron Airship (1933)

Avro Triplane IV (1910)

Pegasus XL SE Ultralight

Schleicher K23 Glider

Bell Boeing Tiltrotor

Voyager

Douglas DC-3

Farman F.60 Goliath

Supermarine S.6B Seaplane

McDonnell Douglas F-18 Hornet

Lockheed C-130 Hercules

Bell X-1

Lockheed F-117 Nighthawk

Junkers Ju.52

Boeing Chinook

Discovery (Space Shuttle)

Hughes H-1

Hughes H-4 Hercules

Lockheed L-1011 Tristar

Northrop T-38 Talon

DHC-2 Beaver

Piper Chieftain

Voisin-Farman Biplane

Gloster Meteor

Airbus A340

Lynx (helicopter)

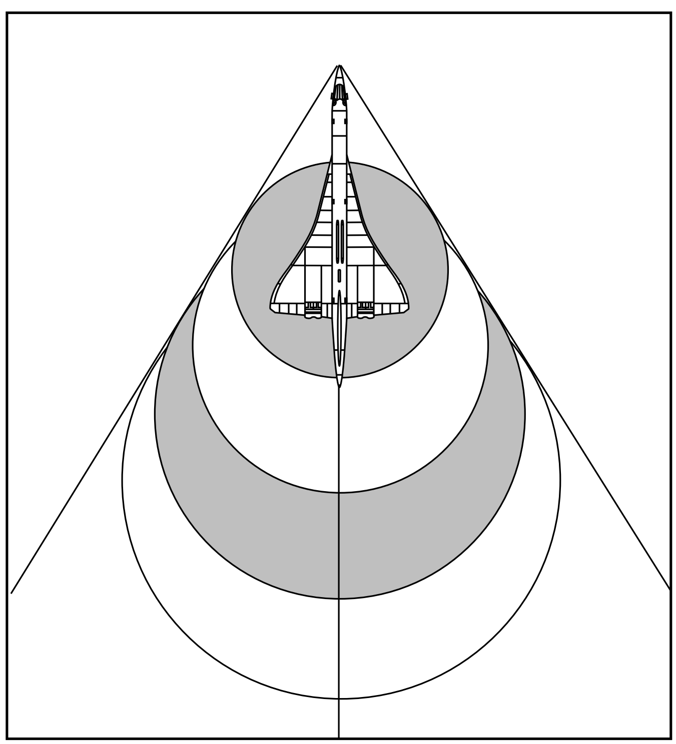
Canadair CL-415

X - 36

Writing Experience: Sound Wave Travel

When sound travels through air it has a very definite effect upon the air molecules. As an airplane moves through airspace at the speed of sound, it causes a big disturbance that results in the "sound barrier being broken". This causes a sonic boom.

Pretend that you and your group of friends are actually molecules floating in the atmosphere. You are located up where the supersonic aircraft fly. In the **first paragraph** describe what the atmosphere is like at that altitude and how you and your group of friends would be acting. In the **second paragraph** describe what happens when a supersonic aircraft flies through your airspace. Describe not only the sounds, but what it would feel like when the wave moves through your group. Would it be disruptive? Would it feel like you were roughly jostled or would it feel more like floating on an ocean wave? Finish your description with a **third paragraph** that describes how all of you would get back to your normal routine as molecules in the atmosphere. Be imaginative and use show-not-tell language. Try to describe things using more than one of your senses. Try adding dialogue as you and your friends talk your way through the experience.



Writing Experience: Airplane Discussion

Using the information gathered from your in-depth aircraft research assignment, work with your group members to write a discussion that takes place among a small group of airplanes. Have each member take on the identity of his/her aircraft and talk about their flight experiences.

Pretending you are the aircraft you researched, and include in the discussion some of your design facts, what kind of work you do, and an experience you might have had during a particular flight.

Use the writing guide below to help you get started on writing your discussion in script form.

Another Day at the Airport Comes to a Close

Vehicle #1: Boy, practicing touch and go landings with that new pilot trainee sure is tough on my undercarriage.

Vehicle #2: Oh, you Cessnas always think your work is so hard. Puttin' around out there is nothing compared to the long hauls I have to make.

Vehicle #3:

Mach and Mile Mathematics with the X-15

Background: The National Aeronautics and Space Administration (NASA) conducts space flight research to collect data on high speed aerodynamics. The X-15 aircraft was used extensively from 1959 - 1968 to fly faster and higher than any aircraft had before. The X-15 was the first aircraft to fly to the edge of space and return to Earth. The results of many X-15 test flights would later be used to design the Space Shuttle.

People who fly and work with high speed aircraft often use the term "Mach number" to describe the speed of an aircraft. "Mach number" was named after an Austrian physicist named Ernst Mach (1838-1916) who studied sound. A Mach number is special because it takes into account both the speed of the aircraft and the environmental condition of the air through which the aircraft is flying.

The Mach number is calculated by dividing the speed of the aircraft by the speed of sound at the altitude the aircraft is flying. Remember to keep the units for speed of the aircraft and the speed of sound the same!

$$\frac{\text{speed of the aircraft in miles per hour}}{\text{speed of sound in miles per hour}} = \text{Mach number}$$

If an aircraft is flying at Mach 1, we say that it is flying at the speed of sound. If an aircraft is flying at Mach 2, we say that it is flying twice the speed of sound. If an aircraft is flying at Mach 6, we say that it is flying six times the speed of sound.

Also, for these exercises you will need to remember that:

one mile = 5,280 feet

Mach and Mile Mathematics with the X-15

Exercise 1

Directions: The X-15 had a very unique way of starting its flights. It was mounted on the belly of a B-52 and flown to an altitude of 45,000 feet, where it was launched at a speed of 500 miles per hour. A rocket in the X-15 would then provide thrust for roughly 120 more seconds, and then the X-15 would glide over 200 miles back to a runway. Navy Test Pilot, A. Scott Crossfield, was the first to fly the X-15.

Many test pilots flew the X-15 during the years it was tested, but two pilots broke world records during their flights. On August 22, 1963, NASA test pilot, Joseph A. Walker, flew the X-15 to an unofficial world altitude record of 354,200 feet. On October 3, 1967, Major William Knight, an Air Force Test Pilot, set the world speed record for winged aircraft. He flew 4,520 miles per hour. One year later, after 199 test flights, the X-15 was retired on October 24, 1968.

Question 1: The world altitude record, set by Test Pilot Walker, was 354,200 feet. What was his altitude in miles?

Question 2: The flight plan for Test Pilot Walker's record-breaking flight called for him to point the nose almost straight up and provide maximum rocket thrust after he was launched from the B-52. If the B-52 launched the X-15 at an altitude of 45,000 feet, how many feet up did he fly to break the altitude record?

Question 3: How many <u>miles</u> upward did he fly to break the altitude record?

He gained almost 90% (that is, almost all!) of his total altitude after he was launched, almost straight up, from the B-52 - in only 120 seconds! How would you like to have gone along for that ride?

Question 4: Can you think of a town that is between 58 and 67 miles away from your hometown? You can check the distance on a map. Does that town seem far away? Imagine going that distance, but going straight up! It might be fun to draw a picture of Test Pilot Walker's record-breaking flight!

Question 5: Test Pilot Major Knight had an equally exciting flight when he broke the world speed record! The old speed record was 4,486 miles per hour. By how many miles per hour did Major Knight beat the old record?

Question 6: The speed limit on most United States highways is 65 miles per hour. How many times faster did Major Knight fly than your car can legally go on the highway?

Question 7: The "speed of sound" is a measure of how fast sounds travel through the air. The "speed of sound" on earth, when the air temperature is 59 degrees, is 762 miles per hour. So, when a friend calls to you from across the schoolyard, the sound comes out of his/her mouth and enters your ears at 762 miles per hour!

The speed of sound changes as altitude and air temperature change. The speed of sound at the altitude at which Major Knight made his record-breaking flight was 87 miles per hour slower than on the ground. What was the speed of sound at Major Knight's altitude?

Question 8: Now that you know the speed of sound at Major Knight's altitude can you calculate the Mach number of the record-breaking flight?

Question 9: If Major Knight was flying Mach 6.7, how many times faster than the speed of sound was he flying?

Mach and Mile Mathematics with the X-15

Exercise 2

Directions: Based on what you learned in Exercise 1, Mach 1 would be one times the speed of sound. At sea level this is roughly 762 miles per hour.

Have you ever traveled at Mach 1?

Probably not! The fastest commercial jet airplanes in the United States generally fly below 500 miles per hour. However, there is a European airliner built by the French, the *Concorde*, that does fly just above Mach 1. If you have flown the *Concorde*, say from Paris to New York, then you are one of a fairly small group of people that has flown faster than the speed of sound!

Most of us have had to be content with driving, riding or flying at less than Mach 1. To see just how far below Mach 1 we generally travel, answer the following questions.

Remember that the speed of sound changes for two reasons. It changes according to altitude and the environmental condition of the air. You will need the following table for your calculations:

Altitude Range	Air Environmental Conditions	Speed of Sound
sea level	59 degrees F	762 miles per hour
20,000 - 30,000 feet	-30 degrees F	693 miles per hour
top of the atmosphere	-67 degrees F	662 miles per hour
350,000 - 360,000 feet		675 miles per hour
outer space	there is no air!	0

Question 1: In the United States the maximum speed limit on a freeway is 65 miles per hour. Assume that this freeway runs right along the ocean and it is a cool day. At what Mach number are you driving if you are driving at the speed limit?

Question 2: Say that you are a very accomplished mountain climber and you have decided to climb Mount Everest, the highest mountain on earth. It takes you many days, but finally you are standing at "the top of the world"! While you are standing there, trying to keep warm in -30 degree F weather, you see an F-14 flying at the same altitude you are standing! As she whizzes past you, the pilot gives you a "thumbs up" to congratulate you for making it to the top. If the pilot was flying at Mach 1, use the table above to determine how many miles per hour she was flying. Hint: Mt. Everest is 29,028 feet tall.

Question 3: How many miles per hour slower did the pilot of the F-14 have to go to achieve Mach 1 at the altitude of Mt. Everest, than you would have to go at sea level?

Question 4: In Exercise 1, Test Pilot Joseph Walker, broke a speed record in the X-15 at an altitude of 354,200 feet. If you were still standing on Mr. Everest, how many feet higher would Test Pilot Crossfield have been than you?

How many miles would that be?

If you were to travel the same number of miles by land from your hometown, where would you be? (Use a map to help you determine your answer.)

Question 5: The Space Shuttle flies at approximately 3,111 miles per hour right before it escapes from our atmosphere and enters outer space. What Mach number is this?

A tricky question: If the Space Shuttle flies 17,000 miles per hour in space, what is its Mach number? (Hint: Remember that the Mach number is a representation of the speed of sound. Think carefully about what affects the speed of sound!)

Question 6: A world class marathon runner can easily run at 15 miles per hour. What mach number is this? Assume he/she is running on the beach.

If he/she were running on the top of Mt. Everest, how much slower could they run to stay at Mach .02?

Aspect Ratio of Wings - Exercise 1

Step 1: Using what your teacher discussed with you about the importance of aspect ratio to flight, follow these steps: Create and draw your own wings below. Give each the same area of 72 square units.

Wing A **Wing B**

Step 2: Label the length and width of each wing.

Step 3: Calculate the aspect ratio for each wing and fill in the table below. Don't forget to include the units!

Wing	**length**	**width**	**area**	**aspect ratio**	**drag ranking**
A					
B					

Step 4: Rank the wings according to the drag that each will create, given their aspect ratios. Rank the wing with the least drag, number 1 and the one with the greatest amount of drag, number 2.

Aspect Ratio of Wings - Exercise 2

Step 1: Using what your teacher discussed with you about the importance of aspect ratio to flight, follow these steps: Create and draw your own wings below. Give each the same area of <u>200 square units</u>.

Wing A **Wing B**

Step 2: Label the length and width of each wing.

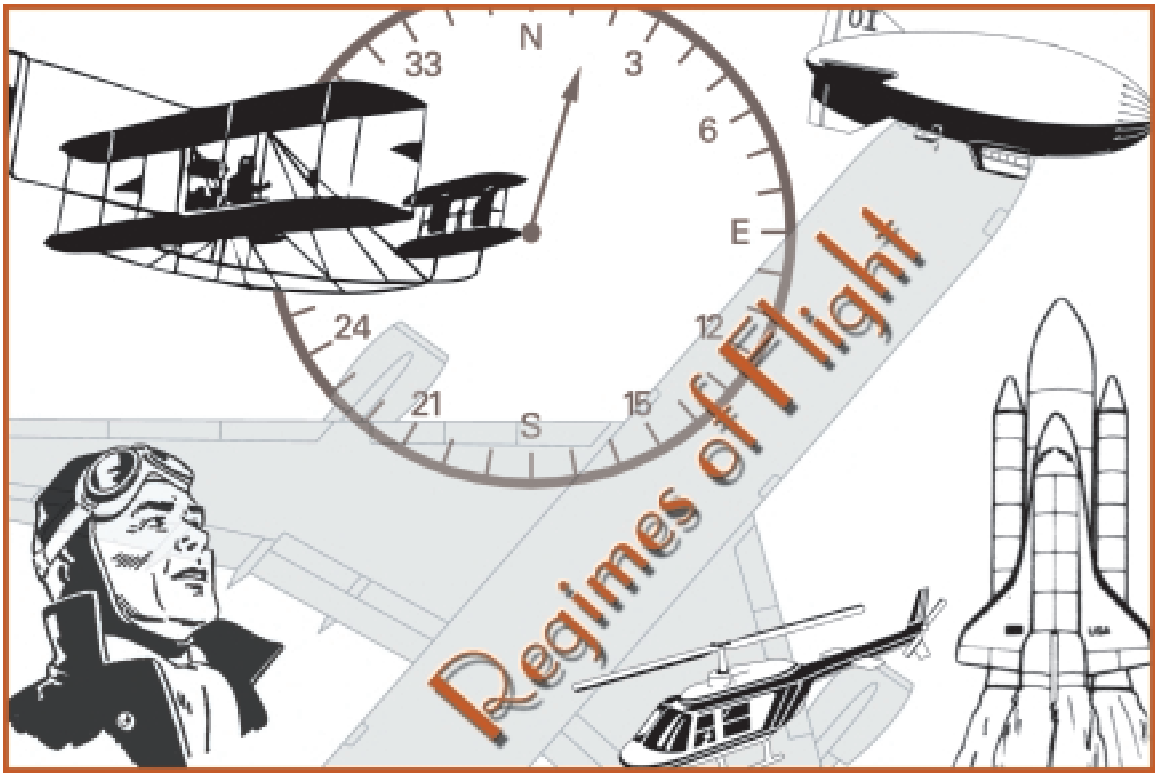
Step 3: Calculate the aspect ratio for each wing and fill in the table below. Don't forget to include the units!

Wing	length	width	area	aspect ratio	drag ranking
A					
B					

Step 4: Rank the wings according to the drag that each will create, given their aspect ratios. Rank the wing with the least drag, number 1 and the one with the greatest amount of drag, number 2.

Student Handouts

Experiments



Experiment: Air Has Weight
Procedure Card

Materials

2 balloons of equal size

string or thread

yard (meter) stick

tape

straight pin

Experiment Set Up

- Inflate both balloons as equally as possible.
- Find the center of gravity for the stick and tie the string around that point leaving a length of 10 inches.
- Cut two equal lengths of string.
- Tape one end of a piece of string to one end of the stick and tape the other end to a balloon.
- Repeat with the other balloon and string.
- Double-check the center of gravity on the stick.

Experiment Procedure

1. Hold stick horizontally by string tied at its center of gravity.
2. Observe and record.
3. Take the pin and carefully pop the balloon so that it does not disintegrate into small pieces. It is important to keep the balloon intact when releasing the air from it.
4. Hold stick horizontally by the string.
5. Observe and record.

Experiment: Air Has Weight

Steps	Data
1. State the problem. **QUESTION** *(What do I want to know?)*	
2. Form a hypothesis. **PREDICTION** *(What do I think is going to happen?)*	
3. Design an experiment. **MATERIALS & PROCEDURES** *(What steps will I take to do this experiment? What things will I need?)*	

Experiment: Air Has Weight

Steps	Data
4. Perform the experiment. **OBSERVE and RECORD DATA** *(What information did I gather during this experiment?)*	
5. Organize and analyze data. *(Make a graph, chart, picture or diagram.)*	
6. Draw conclusions. *(What do my results mean? Was my hypothesis right or wrong? Can I explain why?)*	

Experiment: Air Has Stuff in It
Procedure Card

Materials

dry handkerchief or small cloth

tape

wide mouth jar (empty and dry)

basin with water

Experiment Set Up

- Fill basin with approximately 6 inches of water.
- Bunch up cloth and secure it inside the bottom of the empty, dry jar (with tape if necessary). Secure it in such a way that it will not drop down when the jar is turned upside down.

Experiment Procedure

1. Hold the bottle upside down so that the mouth is perpendicular to the water.
2. Quickly place the upside-down bottle straight down into the basin of water.
3. Hold it firmly down on the bottom of the basin.
4. Observe and record.
5. Withdraw the bottle by quickly bringing it straight up from the bottom of the basin.
6. Pull out the piece of cloth.
7. Observe and record the state of the cloth and the inside of the bottle.

Experiment: Air Has Stuff in It

Steps	Data
1. State the problem. **QUESTION** *(What do I want to know?)*	
2. Form a hypothesis. **PREDICTION** *(What do I think is going to happen?)*	
3. Design an experiment. **MATERIALS & PROCEDURES** *(What steps will I take to do this experiment? What things will I need?)*	

Experiment: Air Has Stuff in It

Steps	Data
4. Perform the experiment. **OBSERVE and RECORD DATA** *(What information did I gather during this experiment?)*	
5. Organize and analyze data. *(Make a graph, chart, picture or diagram.)*	
6. Draw conclusions. *(What do my results mean? Was my hypothesis right or wrong? Can I explain why?)*	

Experiment: The Force of Thrust

Procedure Card

Materials

elongated balloon
tape
soda straw
three meters of fishing line, secured at one end

Experiment Set Up

Secure one end of the fishing line to a wall or sturdy table leg, etc.

Tape the straw length-wise to the elongated balloon.

Inflate the balloon, but do not tie it off. Pinch the mouth closed.

Thread the unsecured end of the fishing line through the straw so that the mouth of the balloon is not pointed toward the secured end.

Experiment Procedure

1. Pull the fishing line tight and release the mouth of the balloon.
2. Observe and record.

Experiment: The Force of Thrust

Steps	Data
1. State the problem. **QUESTION** *(What do I want to know?)*	
2. Form a hypothesis. **PREDICTION** *(What do I think is going to happen?)*	
3. Design an experiment. **MATERIALS & PROCEDURES** *(What steps will I take to do this experiment? What things will I need?)*	

Experiment: The Force of Thrust

Steps	Data
4. <u>Perform the experiment.</u> **OBSERVE and RECORD DATA** *(What information did I gather during this experiment?)*	
5. <u>Organize and analyze data.</u> *(Make a graph, chart, picture or diagram.)*	
6. <u>Draw conclusions.</u> *(What do my results mean? Was my hypothesis right or wrong? Can I explain why?)*	